Linking Social Behaviour and Anxiety to Attention to Emotional Faces in Williams syndrome

Hannah E. Kirk[1], Darren R. Hocking[1], Deborah M. Riby[2] & Kim M. Cornish[1]

1. School of Psychology and Psychiatry, Monash University, Australia

2. Department of Psychology, Durham University, UK

Correspondence to: Miss Hannah Kirk, School of Psychology and Psychiatry, Faculty of Medicine, Monash University, Building 17, Clayton, VIC 3800. Tel: +61 (03) 99050230. Email: hannah.kirk@monash.edu

Abstract

The neurodevelopmental disorder Williams syndrome (WS) has been associated with a social phenotype of hypersociability, non-social anxiety and an unusual attraction to faces. The current study uses eye tracking to explore attention allocation to emotionally expressive faces. Eye gaze and behavioural measures of anxiety and social reciprocity were investigated in adolescents and adults with WS when compared to typically developing individuals of comparable verbal mental age (VMA) and chronological age (CA). Results showed significant associations between high levels of behavioural anxiety and attention allocation away from the eye regions of threatening facial expressions in WS. The results challenge early claims of a unique attraction to the eyes in WS and suggest that individual differences in anxiety may mediate the allocation of attention to faces in WS.

Key words: Williams Syndrome, anxiety, eye gaze, emotional expressions, social responsiveness.
Word Count: 4,500

Williams syndrome (WS) is a rare (1:7,500 to 1:20,000) neurodevelopmental disorder resulting from a microdeletion of approximately 25-28 genes on chromosome 7q11.23 (Donnai & Karmiloff-Smith, 2000; Stromme, Bjornstad, & Ramstad, 2002). At the cognitive level, individuals with WS have mild to moderate intellectual difficulties with relative proficiency in language and short term verbal memory (Mervis et al., 2000) alongside more profound weaknesses in visuospatial and visuomotor abilities (Bellugi, Lichtenberger, Jones, Lai, & St George, 2000; Hocking, Bradshaw, & Rinehart, 2008). At the behavioural level, WS is associated with a distinctive profile of increased social drive, non-social anxiety, and empathic and gregarious emotional personalities (Plesa-Skwerer, Sullivan, Joffre, & Tager-Flusberg, 2004). Of particular interest is the social phenotype of compulsion to engage and approach both familiar and unfamiliar people referred to as hypersociability or prosocial drive (Frigerio et al., 2006; Jones et al., 2000). Once individuals with WS are engaged in social interactions they have been shown to exhibit further atypicalities such as an unusual attraction to the human face, in particular an intense focus of attention to the eye region (Porter, Shaw, & Marsh, 2010; Riby & Hancock, 2009). Despite a characteristic social profile for WS that has been emphasised in the extant literature, there is considerable variability in genetic, cognitive and social functioning that suggests a more nuanced approach is warranted.

Although individuals with WS might show prolonged attention to faces within their environment, they are far from experts at processing and interpreting information from them. There may be a breakdown between attention allocation to faces, perception of appropriate facial cues, and the more sophisticated and cognitive interpretation of faces. Atypical strategies have been unveiled during face processing in WS, with visual focus being directed to specific areas within the face (e.g. eyes and the mouth), and the use of a piecemeal structural encoding strategy rather than a typical configural encoding strategy (e.g. Isaac & Lincoln, 2011). Studies that have employed eye tracking techniques have provided evidence that individuals with WS demonstrate a reduced ability to disengage attention from the eye region of a face when compared to mental-age (MA) matched controls (Porter et al., 2010; Riby & Hancock, 2009). In addition, emotional expressions of faces have been shown to influence attention allocation, with positive (happy) emotions yielding greater visual attention than negative emotions (fearful, angry) in faces (Dodd & Porter, 2010; Plesa-Skwerer, Faja, Schofield, Verbalis, & Tager-Flusberg, 2006; Santos, Silva, Rosset, & Deruelle, 2010). The findings of atypical attention to positive emotional faces, specifically the eye region of faces in WS, are consistent with previous evidence of the role of the amygdala in directing visual attention (Gamer & Buechel, 2009; Gamer, Zurowski, & Buechel, 2010). Functional imaging (fMRI) studies have revealed that WS individuals exhibit anomalous amygdala activation—

that is, both reduced amygdala activation for threatening fearful faces (Meyer-Lindenberg et al., 2005), and heightened amygdala reactivity to happy facial expressions (Haas et al., 2009). It is possible that amygdala abnormalities may offer an explanation for the indiscriminate social approach behaviours associated with WS. However, atypical amygdala responses to emotional faces have also been shown in the neurodevelopmental disorder autism, which is characterised by social withdrawal and reduced visual attention to the eye region of faces, coupled with heightened amygdala responses to direct gaze (Dalton et al., 2005; Riby & Hancock, 2009a; 2009b). These disorders clearly have opposing socio-cognitive profiles associated with anomalous amygdala reactivity; however the nature of the relationship between visual attention to faces and social behavioural characteristics in WS is yet to be fully characterized.

Despite the opposing profiles of atypical social functioning between WS and autism, existing studies have revealed considerable heterogeneity in social functioning, in particular, elevated rates of reciprocal social difficulties and socio-communicative abnormalities in a large proportion of young children with WS suggestive of some overlap with autism spectrum disorders (Klein-Tasman, Li-Barber, & Magargee, 2011; Klein-Tasman, Mervis, Lord, & Phillips, 2007). As such anxiety has been implicated in atypical social interaction in both groups (e.g. Klein-Tasman et al., 2011), and higher levels of social anxiety have been associated with greater amygdala activation to emotional faces in ASD (Kleinhans et al., 2010). Thus it is possible that eye-gaze allocation to emotional facial expressions may be related to variation in levels of anxiety and social impairments in WS. In recent years, evidence has suggested that alongside increased sociability exists a strikingly opposing profile of increased non-social anxiety in WS (Leyfer, Woodruff-Borden, Klein-Tasman, Fricke, & Mervis, 2006; Dodd, Schniering, & Porter, 2009). In particular, high levels of generalised anxiety disorder (GAD) as well as disorder specific fears and phobias have been identified in individuals with WS (Blomberg, Rosander, & Andersson, 2006; Rodgers, Riby, Janes, Conolly & McConachie , 2012). Existing studies have suggested that individuals with WS may use their hypersociable behaviours to mask any underlying anxiety in social interactions (Dykens, 2003); however, the previously reported heterogeneity in the socio-cognitive profile has often been overlooked, (but see Little et al., 2013). Indeed a more recent study showed that atypical attention to face regions was associated with variation in social functioning during mental state recognition (Hanley et al., in press). Although research has sought to probe the nature of visual attention allocation to emotional facial expressions in WS, the interactive influences of behavioural characteristics such as anxiety and social reciprocity are yet to be fully understood.

Current Study

The purpose of the present study was to examine attentional allocation to regions of emotional facial expressions, and the interactive influences of anxiety and social reciprocal behaviours in WS. Thus the aims of the current study were threefold: firstly, we aimed to examine the interplay between visual attention and emotional facial expressions in adolescents and adults with WS. Consistent with previous studies showing greater attention for happy faces in WS (Dodd & Porter, 2010; Porter et al., 2010); we hypothesised that individuals with WS would show greater visual attention to happy facial expressions relative to both mental age (MA) and chronological age (CA) matched controls. Secondly, we aimed to investigate visual attention in relation to specific regions within emotionally expressive faces (e.g. mouth and eye regions). Based on previous studies showing atypical attention to eye regions of faces (e.g. Riby & Hancock, 2008; Porter et al., 2010), we hypothesised that individuals with WS would allocate more attention to the eye region of emotional faces when compared to both MA and CA matched controls. Thirdly, we aimed to explore the relationship between behavioural aspects of anxiety and reciprocal social behaviour and attentional allocation to emotional expressions and face regions in WS. On the basis of previous studies showing that anxiety mediates amygdala response to direct eye gaze to threatening faces in ASD (Kliemann, Dziobek, Hatri, Baudewig, & Heekeren, 2012), we expected that individuals with WS who display higher levels of anxiety and social reciprocity difficulties would show reduced attention to the eye region of threatening facial expressions.

Method

Participants

Thirteen individuals with a diagnosis of WS were recruited via the Williams Syndrome Family Support Group (Victoria), as well as an existing research database. All participants with WS has previously been diagnosed phenotypically and had also previously had their diagnosis confirmed with positive fluorescent *in situ* hybridization testing detecting the absence of one copy of the elastin gene. Participants with WS were individually matched to two typically developing groups based on gender and on either i) chronological age (CA) or ii) verbal ability (VMA; see Table 1). The typically developing CA and VMA groups were recruited through social networks and via online and print advertisements. Verbal ability was assessed using the *British Picture Vocabulary Scale II* (BPVS; Dunn, Dunn, Whetton & Burley, 1997). This receptive vocabulary scale has previously been used to match individuals with WS with typically developing comparison groups (e.g. Jarrold, Cowan, Hewes, & Riby, 2004; Rhodes, Riby, Matthews, & Coghill, 2011).

All participants spoke fluent English and were screened in a previous study for visual deficits (e.g. strabismus, reduced visual acuity, amblyopia, reduced stereopsis). An independent samples *t* test revealed that there was no significant difference in verbal ability between the WS and VMA controls $t(24) = 0.21$, $p=.83$, nor were there significant differences in chronological age between WS and CA controls, $t(24) = 0.42$, $p=.68$).

(Insert Table 1)

Materials

Anxiety

Anxiety was assessed using the *Spence Children's Anxiety Scale* (SCAS; (Spence, 1998). The SCAS is a parent report measure which assesses anxiety symptoms using the DSM-IV classification for childhood anxiety disorders (APA, 1994). The scores produce six inter-correlated factors: separation anxiety, generalised anxiety, social phobia, panic/agoraphobia, obsessive-compulsive disorder, and fear of physical injuries. The parent report version was used for both WS and VMA matched groups, but was not relevant for use in the CA matched group. Despite some of the WS group being adults, self-reports were not deemed appropriate due to the limited intellectual capacity of this group. The SCAS has good internal consistency with a coefficient of greater than .90, adequate test-retest reliability over 6 months and good convergent and discriminant validity (Spence, 1998). Total SCAS scores of 24 or above have been suggested as an indicator of elevated levels of anxiety and this measure has previously been used with WS individuals (see Rodgers et al., 2012).

Social Behaviour

The *Social Responsiveness Scale* (SRS; Constantino & Gruber, 2005) was used to assess social reciprocity impairments characteristic of autism spectrum disorders. The measure consists of 65 items and generates both a total score as well as scores across five treatment subscales: social awareness, social cognition, social communication, social motivation and autistic mannerisms. T scores were used in the interpretation of the test results to allow a comparison against age and gender norms. This measure has previously been shown to be appropriate for use with WS individuals (see Klein-Tasman et al., 2011).

Emotion Recognition

Face stimuli were high quality static images of emotional expressions from the Amsterdam Dynamic Facial Expression Set (ADFES: (van der Schalk, Hawk, Fischer, & Doosje, 2011). Four identities were selected (50% female, 50% male and 50% North European, 50% Mediterranean), and four basic expressions plus a neutral expression was used (angry, fearful, happy, sad and neutral). The faces have previously been validated according to expression in typically developing adults, and have been reported to show excellent recognition rates (see (van der Schalk et al., 2011).

(Insert Figure 1)

Each face was presented on screen for 4 seconds (see Figure 1 for stimuli example). The images measured 1020 x 876 pixels and were overlaid on to a black background. To reduce any impact of memory differences across groups, the five possible emotional expression answers were presented in word and pictorial form on the screen immediately after the 4 second display period. These emotion cues remained on the screen until the participant had verbally stated which emotion they thought was the most appropriate. A centrally positioned fixation cross measuring 60 x 60mm was presented between trials. Participants completed 20 trials (4 identities each displaying 5 emotional expressions; order randomised), and the experiment lasted between 5-10 minutes depending on how long the participant took to give their response to each trial (which was self-paced).

Eye Tracking

While participants viewed emotional expressions their eye movements were recorded. Horizontal and vertical displacements of the eye were binocularly recorded using a video-oculographic SR Research Eyelink 1000 desktop mounted eye tracker. The pupil-corneal-reflection method was used with a sampling rate of 500Hz. A head and chin rest enabled stabilization of the head during recording, and was centred at a distance of 84cm from the display screen. Screen-based stimuli were generated using the SR Research Experiment Builder software version 1.10.165 and displayed on a 22inch LCD monitor with a resolution of 1680 x 1050pixels. Stimuli were presented in a moderately lit room with participants seated on a height-adjustable chair. A five point calibration was used at the start of each testing block.

Procedure

Each participant was tested on a single occasion in a quiet room. Participants were informed that they would be presented with faces displaying a variety of emotions. In the emotion recognition task, the five emotions were initially shown to the participant in both visual and written form; a brief description of each emotion was given by the experimenter. Participants were then asked to label the emotional expression portrayed by the person displayed on the screen. It was made clear to participants that they should take their time when responding as this was a test of accuracy rather than response speed. Participants were prompted for a response when these emotion cues were present with the experimenter asking, 'how do you think that person feels?'

Data Analysis

To investigate fixations to specific facial regions when viewing emotional expressions, areas of interest (AOI) were designated to the face, eyes and mouth regions. For analysis purposes, we were interested in attention allocation to the face region and the most important communicative face regions of the eyes and mouth. These AOIs were marked using the SR Research Data Viewer (see Figure 2 for an example of these AOI). The SR Research computer software recorded the percentage of the trial that was spent fixating on the face region. In order to assess the specific region that individuals were looking at within the face, the time spent fixating on the mouth and eyes was calculated as a percentage of the overall time spent viewing the whole face. Normal distributions for the derived measures were tested using normal probability plots and the Shapiro-Wilk test of normality. 2-way repeated measure ANOVA's were conducted to assess attention allocation to emotion expressions and regions within the face. Post hoc comparisons were conducted using independent sample *t* tests. We considered the uncorrected *p* value of .05 to indicate significance in order to reduce the possibility of Type II error given the small sample size which is common in a rare syndrome such as WS (see Rothman, 1990).

(Insert Figure 2)

Results

Emotion Recognition Ability

A 2-way repeated measures analysis of variance (ANOVA) was conducted, with factors Group (WS, CA, VMA) and Emotion (neutral, fearful, sad, happy, and angry). There was a significant main effect of Emotion, $F(2,36) = 7.347$, $p=.001$, and a significant main effect of Group, $F(2,36) = 9.972$, $p=.001$. The interaction between group and emotion showed a trend towards significance (*p*=.06; see Table 2 for mean accuracy across groups and emotion). Some caution is required due to ceiling effects in the typically developing groups which may mask between group differences. An independent samples *t* test showed that WS and VMA groups did not differ significantly in their performance on any emotion item. The interaction between group and emotion was therefore driven by a difference between the CA and WS groups on some, but not all emotions (see Table 2). The WS group were significantly less accurate than the CA group for the expressions of fear, $t(24) = -2.72$, $p=.01$, and sadness $t(24) = -3.57$, $p=.003$, and the neutral expression, $t(24) = -2.52$, $p=.03$, but not for the happy or angry expressions.

We note that caution is required here as the lack of difference between groups for some emotional expressions may be driven by ceiling effects. However, the main interest for this study concerns the attention allocation when individuals with WS and those who are developing typically attend to, and process, these facial expressions.

(Insert Table 2)

Social and Behavioural Characteristics

The WS group were rated higher on various subscales of anxiety on the SCAS than VMA matched typically developing individuals and showed parent ratings above the clinical cut-off for anxiety disorders. There were significant group differences on subscales of Panic attack/agoraphobia [$t(23) = 2.63$, $p < .05$], Fear of physical injury [$t(23) = 3.45$, $p < .05$], Generalised anxiety disorder [$t(23) = 2.80$, $p < .05$] and the Total SCAS score [$t(23) = 2.44$, $p < .05$] (See Table 3). Within the WS group, 58% of the individuals scored within the clinical range of elevated anxiety levels. Additionally, the WS group showed significantly more problems in social reciprocity as measured by the SRS than VMA controls. Significant group differences were found on the subscales of Social Awareness [$t(20) = 3.51$, $p < .01$], Cognition [$t(20) = 4.53$, $p < .01$], Communication [$t(20) = 3.62$, $p < .01$], and Mannerisms [$t(20) = 4.19$, $p < .01$].

(Insert Table 3)

(Insert Table 4)

Gaze Fixation Patterns

Visual Attention to Emotional Expressions

A repeated measures ANOVA with factors Group (WS, CA, VMA) and Emotion (neutral, fearful, happy, sad, angry) on gaze fixation patterns revealed a significant main effect of Emotion, $F(2,35) = 91.01$, $p=.001$. Overall the amount of time spent attending to faces differed depending on the emotion being expressed. Table 4 shows that all groups attended to the sad expressions for a shorter period of time than the other expressions. The main effect of Group was also significant $F(2, 35) = 4.62$, $p=.02$. Therefore, the groups differed in their overall attentional engagement with the emotionally expressive faces. Post hoc analyses were conducted to assess any significant differences across the groups. Independent samples *t* tests showed that the WS group spent a significantly smaller percentage of the trial fixating on fearful face regions than the CA group, $t(23) = -2.66$, $p=.02$. In contrast, the WS group was shown to spend a larger percentage of the trial fixating on happy face regions than the MA group, $t(23) = 2.14$, $p=.04$. The interaction between emotion and group was not significant ($p=.41$).

Visual Attention to Face Regions

Due to a significant difference in attentional engagement to the face across groups, the proportion of time spent fixating on the mouth and eyes was calculated as a percentage of time spent fixating on the whole face. A repeated measures ANOVA with factors Group (WS, CA, MA), Emotion (neutral, fearful, happy, sad, angry) and Region (mouth, eyes) revealed significant main effects for Region, $F(2,35) = 109.99$, $p=.001$, and Emotion $F(2, 35) = 45.40$ $p=.001$. The main effect of Group was also significant, $F(2,35) = 5.293$, $p=.01$. Overall participants allocated more attention to the eye region than the mouth region (see Table 4). However, there was a significant 3 way interaction between Group, Emotion and Region, $F(2,35) = 4.42$, $p=.004$. There were additional 2 way interactions between Emotion and Region, $F(2,35) = 34.23$, $p=.001$, and Emotion and Group $F(2,35) = 4.455$, $p=.009$, but the interaction between Region and Group did not reach significance ($p=.09$).

To further explore the significant three way interaction, separate ANOVAs with the within subject factors Emotion (neutral, fearful, happy, sad, angry) and Region (mouth, eyes) for each group revealed a significant interaction between region and emotional expression for both VMA, $F(1,12) = 31.37$, $p=.001$, and CA typically developing groups, $F(1,12) = 28.02$, $p=.001$, but not for the WS group ($p=.35$). The CA group attended to the eyes for longer than the mouth for all expressions (fearful, $p=.001$; happy, $p=.002$; sad, $p=.001$; angry, $p=.001$; neutral, $p=.001$). The VMA groups attended to the eyes longer than the mouth for all expressions (fearful, *p*=.001; sad, *p*=.001; angry, *p*=.001; neutral, *p*=.001), except happy where attention to these regions was equivalent between the eyes and mouth region (*p*=.23).

Relationships between visual attention, task performance and verbal ability

For the WS group, there was no significant association between task difficulty measured by the accuracy of performance on the emotion recognition task and gaze fixations. This was consistent for each region (eyes and mouth) and across each emotion. In addition, verbal ability as measured by the BPVS was not shown to correlate with gaze fixation patterns across specific regions or emotions. It should be noted that verbal ability in WS was associated with performance on the emotion recognition task for some but not all of the emotional expressions, angry (r=-.61, *p*<.05).

Relationships between visual attention, anxiety and social reciprocity

Pearson correlations were conducted for the SCAS and SRS subscales that were shown to be significantly different between WS and VMA controls. For individuals with WS, there was a significant association between increased levels of generalised anxiety and reduced fixation on faces for individuals with WS (r=-.69, *p*<.05), and reduced attention to the eye region (r=-.62, *p*<.05). In particular, increased levels of generalised anxiety were significantly associated with reduced attention to the eye region (r=.67, *p*<.05), and increased attention to the mouth region of fearful emotional faces (r=.61, *p*<.05). In addition, reduced attention to the eye region of angry emotional faces was also significantly associated with increased levels of generalised anxiety (r=-.61, *p*<.05) (see table 5).

(Insert Table 5)

There were no significant associations between social reciprocity difficulties and fixations to specific emotions or facial regions for individuals with WS. However, Pearson correlations showed that there was a significant positive correlation between SRS total score and SCAS total score for WS individuals (r=.76, *p*<.01) but not VMA controls (r=.42). There was also a significant correlation with the SRS total score and the SCAS subscale, GAD for the WS group (r=.64, *p*<.05). Additionally, total SCAS scores in WS individuals were shown to be positively correlated with several SRS subscales including, Awareness (r=.81, *p*<.01), Communication (r=.65, *p*<.05), and Mannerisms (r=.67, *p*<.05). Pearson correlations show that verbal ability was not correlated to SCAS total scores for the WS group (r=-.47), but there was a significant negative correlation between SRS total score and verbal ability for the WS group (r=-.64, *p*<.05) in that better social functioning was associated with higher verbal ability.

Discussion

This study is the first to examine the relationships between atypical gaze distribution to emotionally expressive faces and socio-emotional behavioural characteristics associated with anxiety and social reciprocity in WS. Contrary to the hypothesis of atypically prolonged eye-gaze behaviour in WS (e.g. Riby & Hancock, 2009; Porter et al., 2010), the current findings suggest that adolescents and adults with WS on average do not spend more time fixating on the eye region of faces compared to chronological age (CA) and verbal mental age (VMA) matched typically developing controls. Our findings appear to be explained by the increased levels of anxiety and considerable variability in both anxiety and reciprocal social functioning in our WS group. As hypothesised, levels of elevated anxiety in WS, specifically generalised anxiety were associated with reduced fixation to the eye region and prolonged fixation to the mouth region of fearful faces. These findings extend previous studies which have demonstrated substantial heterogeneity in the social profile in WS (Jarvinen-Pasley et al., 2010; Hanley et al., in press; Porter & Coltheart, 2005), and suggest that heightened anxiety may influence attentional allocation and avoidance processing of socially meaningful stimuli in some individuals with WS.

The current findings are in contrast with several previous eye tracking studies which have shown atypically prolonged eye gaze and problems in disengaging from the eye region of emotional faces in WS (Porter et al., 2010; Riby & Hancock, 2009a; 2009b). Our results showing no differences in gaze behaviour toward a particular feature of emotional faces challenges early claims of a unique attraction in WS to the eyes of faces. However, more recent studies point to the importance of examining individual differences in reciprocal social functioning with many (half the sample) but not all individuals with WS showing difficulties with socio-emotional communication and social reciprocity (Klein-Tasman et al., 2011; Klein-Tasman, Phillips, Lord, Mervis, & Gallo, 2009; Tager-Flusberg, Skwerer, & Joseph, 2006). This is consistent with a recent study which showed that allocation of attention to face regions during mental state recognition was related to behavioural measures of social functioning (Hanley et al., in press). Consistent with this, our WS group were also rated higher in terms of social reciprocity difficulties than VMA matched controls. These difficulties included social awareness, cognition, communication and mannerisms which are consistent with social deficits in the autism spectrum. Furthermore, there were significant relationships between social reciprocity skills and elevated levels of anxiety in the WS group which may show several interactive influences with eye gaze fixation patterns. Interestingly motivation difficulties in social reciprocity were not displayed in the WS group (this subscale assesses the desire to engage with others), despite elevated levels of anxiety thus providing support for the contention that hypersociability in WS may be masking underlying anxiety (Dykens, 2003). Specifically, our findings revealed that parent-reported generalised anxiety levels were associated with less time fixating on the eye regions of threatening emotional faces (both fearful and angry) in the WS group. Together these findings provide a new perspective on abnormalities in gaze towards threatening facial expressions in WS, and suggest that differential allocation to face regions (fixation versus avoidance of eye region) may be a function of anxiety severity.

The association between high levels of generalised anxiety and gaze orienting away from the eye regions of threatening faces in WS is intriguing as it may reflect the interactive effect of anxiety on amygdala reactivity during the processing of facial expressions. Although previous studies examining the neural basis of social cognition in WS have revealed reduced amygdala activation to threatening (fearful) emotional facial expressions (Haas et al., 2010; Haas et al., 2009; Meyer-Lindenberg et al., 2005), these past studies have not considered the impact of individual differences in anxiety and deficits in social reciprocity. These links have however been made in studies investigating gaze patterns in ASD. Indeed, diminished fixation to the eye region has been associated with greater levels of social anxiety in ASD independent of autism severity (Corden, Chilvers, & Skuse, 2008) as well as amygdala hyper-responsiveness (Dalton et al., 2005; Kliemann et al., 2012). Interestingly, the atypical gaze patterns away from threatening eyes did not result in poorer recognition of fearful or angry faces in our WS group relative to their developmental level, providing the preliminary suggestion that gaze away from this region may be more related to the effects of enhanced arousal than reduced attention to the eye region. This interpretation would be consistent with the atypical gaze patterns in ASDs. Together, these findings provide new insights into the role of anxiety as a possible interactive influence on attention to emotionally threatening stimuli which may contribute to individual variations in avoidance processes and socio-perceptual impairments in WS.

Several limitations should be considered in the current study. First, there was no direct comparison of the WS group to individuals with autism and so we cannot determine whether the deficits in social reciprocity and anxiety differentiate the two disorders based on atypical gaze behaviour. In addition, the correlations between the measures of social reciprocity and anxiety may be driven by common method variance, and therefore the correlations should be interpreted with caution as these behavioural scales may tap into some overlapping domains. An additional limitation related to recruitment feasibility is the relatively small sample size of the WS group included in the current study. However, our participant characteristics are comparable to those used in previous eye tracking studies that have involved individuals with WS, largely due to the prevalence of the disorder and compliance with eye tracking techniques (e.g Riby & Hancock, 2008, 2009; Porter, Shaw & Marsh, 2010). Future studies will need to incorporate more direct physiological measures of arousal as well as functional imaging techniques to investigate how differential amygdala reactivity is related to variability in anxiety and social reciprocity behaviours in WS. Furthermore, on the basis of the regulatory effect of the neuropeptide oxytocin on social behaviour, amygdalar responses and eye gaze (Gamer et al., 2009; Gamer et al., 2010), it will be important for future studies to explore the relationship between endogenous levels of oxytocin, amygdala reactivity and individual differences in anxiety and gaze behaviour toward emotional faces in WS. Together these future studies would provide a more detailed understanding of the role of the amygdala in attention allocation to emotional facial expressions and clarify the previously reported variations in social behaviour in WS (Dai et al., 2012; Haas et al., 2010).

In summary, the current study emphasises the importance of linking gaze orientation toward emotional faces to the variability on behavioural measures of anxiety experienced by individuals with WS. This critical next step in research will allow us to capture individual variability within syndromes in more detail. The significant relationships observed between levels of anxiety and differences in allocation of attention to threatening facial expressions (fixation vs. avoidance of eye region) may contribute to the social reciprocity difficulties which are often overlooked in adolescents and adults with WS. Considering the importance of eye gaze in over-arousal and reduced attention to socially meaningful stimuli in disorders with severe social deficits such as autism (Corden et al., 2008; Dalton et al., 2005), future remediation programmes might focus on anxiety reduction techniques to improve gaze initiation toward all facial features thereby reducing some aspects of social interaction difficulties in WS.

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